Systematic evolution of the magnetotransport properties of $Bi_2Sr_{2-x}La_xCuO_6$ in a wide doping range

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Recently we have succeeded in growing a series of high-quality $Bi_2Sr_{2-x}La_xCuO_6$ crystals in a wide range of carrier concentrations. The data of $\rho_{ab}(T)$ and $R_H(T)$ of those crystals show behaviors that are considered to be "canonical" to the cuprates. The optimum zero-resistance T_c has been raised to as high as 38 K, which is almost equal to the optimum T_c of $La_{2-x}Sr_xCuO_4$.

1. INTRODUCTION

Since the high-T_c cuprates are in essence doped Mott insulators, systematic studies of the evolution of the normal-state properties upon changing the carrier concentration are very useful for elucidating the origin of the peculiar normal state. $Bi_2Sr_2CuO_6$ (Bi-2201) system is an attractive candidate for such studies, because the carrier concentration can be widely changed by partially replacing Sr with La [1]. Moreover, this system allows us to study the normal-state in a wider temperature range, because the optimum T_c (achieved in $Bi_2Sr_{2-x}La_xCuO_6$ with $x\simeq0.4$ [1,2]) has been reported to be about 30 K, which is lower than the optimum T_c of $La_{2-x}Sr_xCuO_4$ (LSCO). However, a number of problems have been known so far for Bi-2201 crystals: (i) the transport properties of Bi-2201 are quite non-reproducible even among crystals of nominally the same composition [3,4]; (ii) the residual resistivity of ρ_{ab} is larger (the smallest value reported to date is 70 $\mu\Omega$cm [4,5]) than other cuprates; and (iii) the temperature dependence of the Hall coefficient R_H is weak and thus the cotangent of the Hall angle θ_H does not obey the T^2 law [3].

In our group at CRIEPI, we have recently succeeded in growing a series of high-quality crystals, in which the above problems have mostly been overcome [6]. Here we report most recent data of $\rho_{ab}(T)$ and $R_H(T)$ of our Bi-2201 crystals in a wide range of carrier concentrations to demonstrate that the normal-state transport properties in those clean crystals display behaviors that are in good accord with other cuprates.

2. SAMPLES

The single crystals of $Bi_2Sr_{2-x}La_xCuO_6$ (BSLCO) are grown using a floating-zone technique. The crystals are annealed in oxygen to sharpen the superconducting transition width. Pure Bi-2201 is an overdoped system [1] and increasing La doping brings the system from overdoped region to underdoped region. In our series of crystals, the optimum doping is achieved with $x\simeq0.4$, which is consistent with previous reports on BSLCO [1,2]. The actual La concentrations in the crystals are determined with the inductively-coupled plasma (ICP) analysis. We note that the optimum zero-resistance T_c reported here is as high as 38 K, which is not only the highest value ever reported for Bi-2201 system but also almost equals that of the LSCO system.

3. RESULTS AND DISCUSSIONS

Figure 1(a) shows the T dependence of ρ_{ab} for eight x values (x=0.23, 0.39, 0.49, 0.51, 0.66, 0.73, 0.76 and 0.84) in zero field. Clearly, both

the magnitude of ρ_{ab} and its slope show systematic decrease with increasing carrier concentration (decreasing x). Note that it is only at the optimum doping (x=0.39) that ρ_{ab} shows a good T-linear behavior: In the underdoped region, $\rho_{ab}(T)$ shows a downward deviation from the T-linear behavior, which has been discussed to mark the pseudogap [7]. In the overdoped region, $\rho_{ab}(T)$ shows an upward curvature in the whole temperature range; the T dependence of ρ_{ab} in the overdoped region can be well described by $\rho_{ab}=\rho_0+AT^n$ (with $n\approx1.2$ for x=0.23), which is a behavior known to be peculiar for the overdoped cuprates [8,9].

Shown in Fig. 1(b) is the T dependence of R_H for the eight samples. Here again, a clear evolution of R_H with x is observed; the change in the magnitude of R_H at 300 K suggests that the carrier concentration is actually reduced roughly by a factor of 5 upon increasing x from 0.23 to 0.84. Note that the T dependence of R_H is stronger than those previously reported [3,10] and that pronounced peaks in $R_H(T)$ are clearly observed in optimally-doped and underdoped samples.

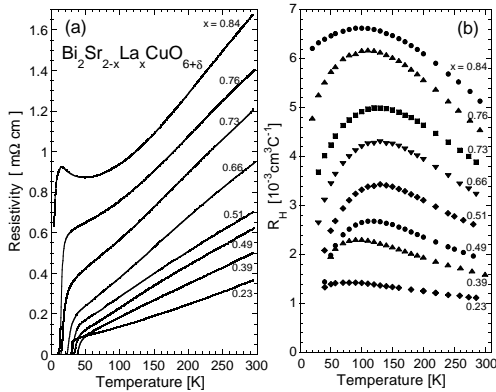When $\cot\theta_H$ is examined, we found that $\cot\theta_H$ obeys a power-law dependence T^α, where α is

Figure 2. $\cot\theta_H$ vs T^α plot for x=0.66 and 0.39.

nearly 2 in underdoped samples but shows a systematic decrease with increasing carrier concentration [6]. Figure 2 shows examples of the $\cot\theta_H$ vs T^α plot, for x=0.66 and 0.39. We note that the T^2 law of $\cot\theta_H$ is confirmed for the first time for Bi-2201 in our crystals.

4. CONCLUSION

We present the $\rho_{ab}(T)$ and $R_H(T)$ data of a series of high-quality La-doped Bi-2201 crystals in a wide range of carrier concentrations. It is shown that the optimum zero-resistance T_c of Bi-2201 can be as high as 38 K. The normal-state transport properties of our Bi-2201 crystals show systematics that are in good accord with other cuprates.

Figure 1. T dependence of (a) ρ_{ab} and (b) R_H of the BSLCO crystals with various x. Note that the extrapolated residual resistivity of x=0.39 sample is 25 $\mu\Omega$cm, which is the smallest value to date for Bi-2201 or BSLCO.
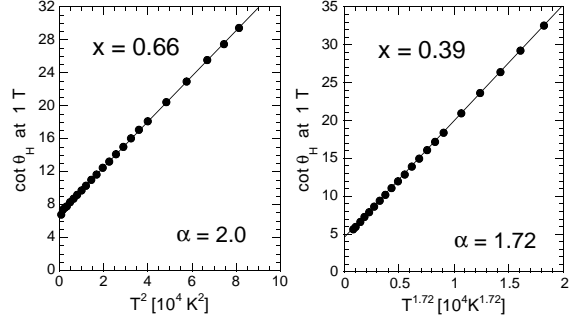
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